Chapter 4 Communications Trunkline Conduit System

4.1 Purpose

The FMS communications system consists of either one or two trunkline conduit systems that run parallel to the mainline freeway. These trunkline conduits provide the primary method of distributing fiber-optic communications cabling and power conductors for the system.

FMS conduits that are not part of the trunkline conduit system are typically called *branch* conduits. Branch conduits connect the trunkline network to the various field cabinets and devices. Within this document, branch fiber-optic cables are described as fiber-optic cables contained within branch conduits.

4.2 Position of Trunkline within Freeway Right-of-Way

The trunkline conduit system shall be located inside and along the edge of the freeway's right-of-way line. Generally, the trunkline conduit should be located as far from the mainline edge of pavement as feasible so that future widening of the mainline freeway will not impact it. The likelihood of future earthwork and re-grading decreases when approaching the right-of-way line. Thus, the trunkline conduit system is less likely to be disturbed by this work.

The designer will have to exercise engineering judgment as to the preferred location for the trunkline conduit system, considering factors such as slopes, cross-section, proximity to retaining walls, sound walls, and landscaping and irrigation systems. Maintenance force access to the trunkline conduit system, usually at pull boxes, should also be considered. The trunkline conduits should be offset from the actual right-of-way fence, where feasible, to avoid repeated maintenance vehicle wheel-loads. Several figures are included to illustrate these design concepts. (See Figures 4.1, 4.2, 4.3, 4.4, 4.5, and 4.8.)

When the freeway is on an embankment section, consideration must be given to placing field equipment, controller cabinets, etc., at the top of slope to provide visibility of the FMS equipment from the cabinet, even though the trunkline remains adjacent to the right-of-way line. In any case, trunkline should not be placed below slopes.

4.3 Trunkline Conduit Array & Layout

This section describes several trunkline conduit configurations intended to complete the existing FMS trunkline conduit system and the future expansion of the FMS in a consistent manner. The industry has dynamically changed over the past few years with regard to conduit systems. Conduit size, trenching/backfill, directional drilling, etc., are among the most expensive yet important elements of the FMS.

4.3.1 Conduit Array: Three-Inch Conduits

The installation of new trunkline conduit along existing urban freeways (Phoenix: Loop 101, Loop 202, SR-51, US-60, I-10, and I-17; Tucson: I-10 and I-19) shall be consistent with a three-inch conduit array. This three-inch conduit array has been used extensively in the existing conduit system and is the ADOT standard.

Future build-out of new routes, such as Loop 202 South Mountain, Loop 303, and the Williams Gateway freeways in Phoenix may be configured with a different conduit array. Alternate conduit systems for future build-out could include quad-ducts and HDPE alternatives (see Section 4.5.2 for a discussion of conduit materials). Future options for innerducts (see Section 4.6) within the conduit system include micro-ducts and flexible fabric innerducts.

Section 4.5.3 provides further discussion of trunkline conduit orientation, including vertical and horizontal configurations.

4.3.2 Conduit Layout

The ADOT FMS in Phoenix is approaching 100% build-out for all freeways interior to Loop 101 and Loop 202. It is ADOT's intention to complete the core FMS by continuing the construction of the three-inch conduit array. Regional connectivity goals for local agencies may require the need for fiber-optic cable installation within the spare conduit, and this issue should be carefully discussed with the ADOT TTG PM.

Trunkline on Both Sides of Freeway

Three 3-inch trunkline conduits are required along both sides of the freeway to accommodate communications cables and power cables, and to provide for future expansion of the FMS. Certain segments of the FMS trunkline may also include a fourth conduit for roadway lighting. The conduit path shall be chosen to provide a continuous conduit system as shown in Figure 4.1 and Figure 4.2. Any deviation from the conduit systems as shown in these figures requires ADOT TTG approval.

Trunkline on One Side of Freeway

The single trunkline configuration will generally be limited to segments where communication redundancy (e.g., a second path to another node building) is immediately available by means other than the second trunkline within the same corridor. The ADOT TTG PM must approve all single trunkline segments prior to design.

Where designated by the ADOT TTG PM, the conduit path for the trunkline conduit system may be constructed on only one side of the freeway. The conduit path for a "one-side" trunkline layout should incorporate the layout shown in Figure 4.3. This layout allows for future construction of the second trunkline on the opposite side of the respective freeway and frequent crossings to connect devices on both sides of the freeway. When the trunkline is constructed on one side of the freeway, it should generally be positioned on the same side of the freeway throughout the length of the freeway segment.

The parallel, deferred second trunkline conduit path should be examined during the initial design phase for costly future installation issues. For example, it is required to place a concurrent second, parallel conduit system over or under a canal, railroad, drainage way, connector ramp, major arterial, etc., along with lateral connections to the primary trunkline, to facilitate future expansion of the FMS.

Figure 4.3 also depicts the recommended construction of a portion of the second trunkline at crossroad interchanges. Portions of a second trunkline must be connected via a crossing of the mainline to the adjacent trunkline. One connection between the two trunklines is required along either side of each major crossroad, railroad, canal, and major drainage pathways. A second optional lateral connection is preferred near the on-ramp connection to the mainline.

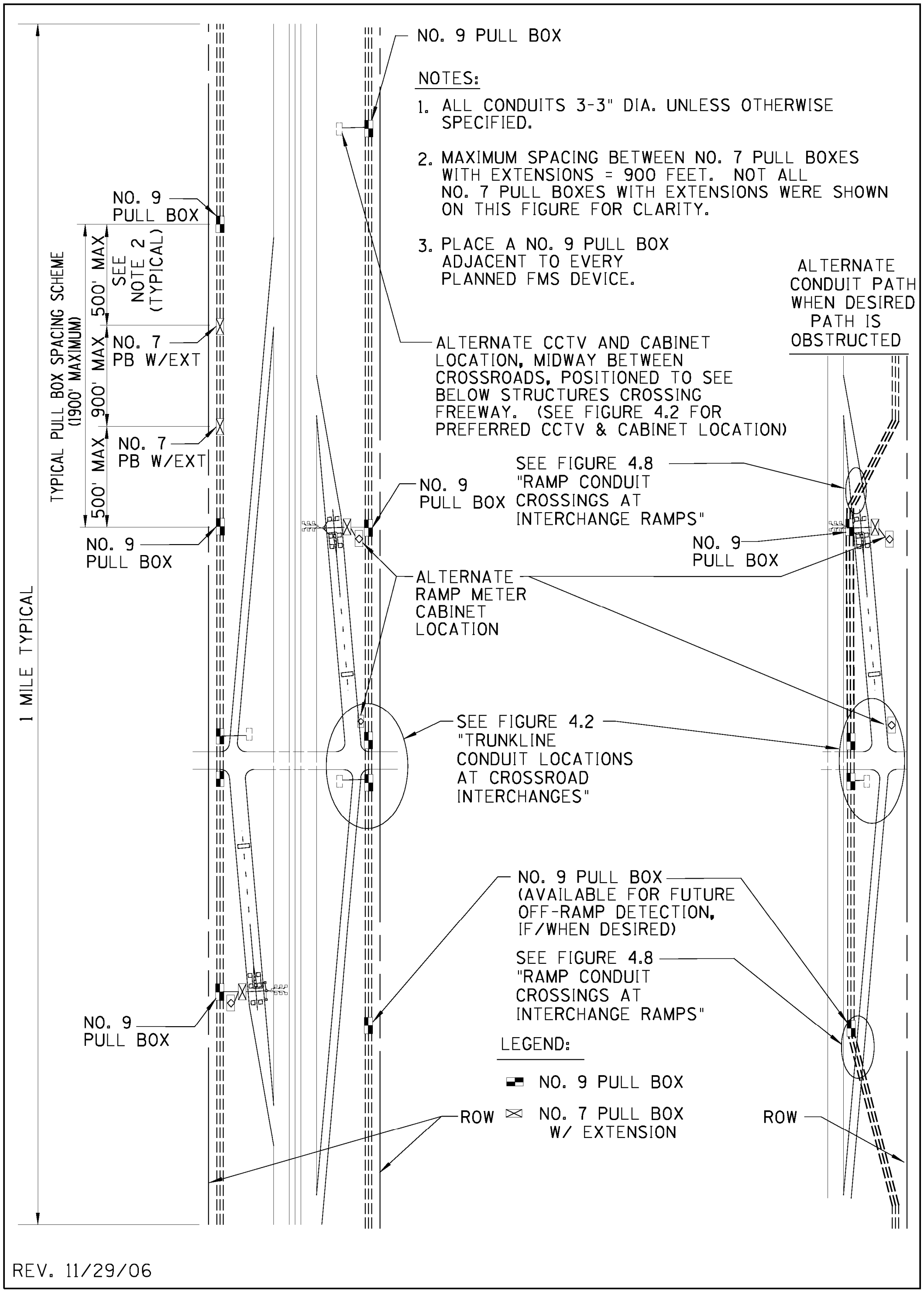


Figure 4.1 Crossroad Interchange Conduit Installation

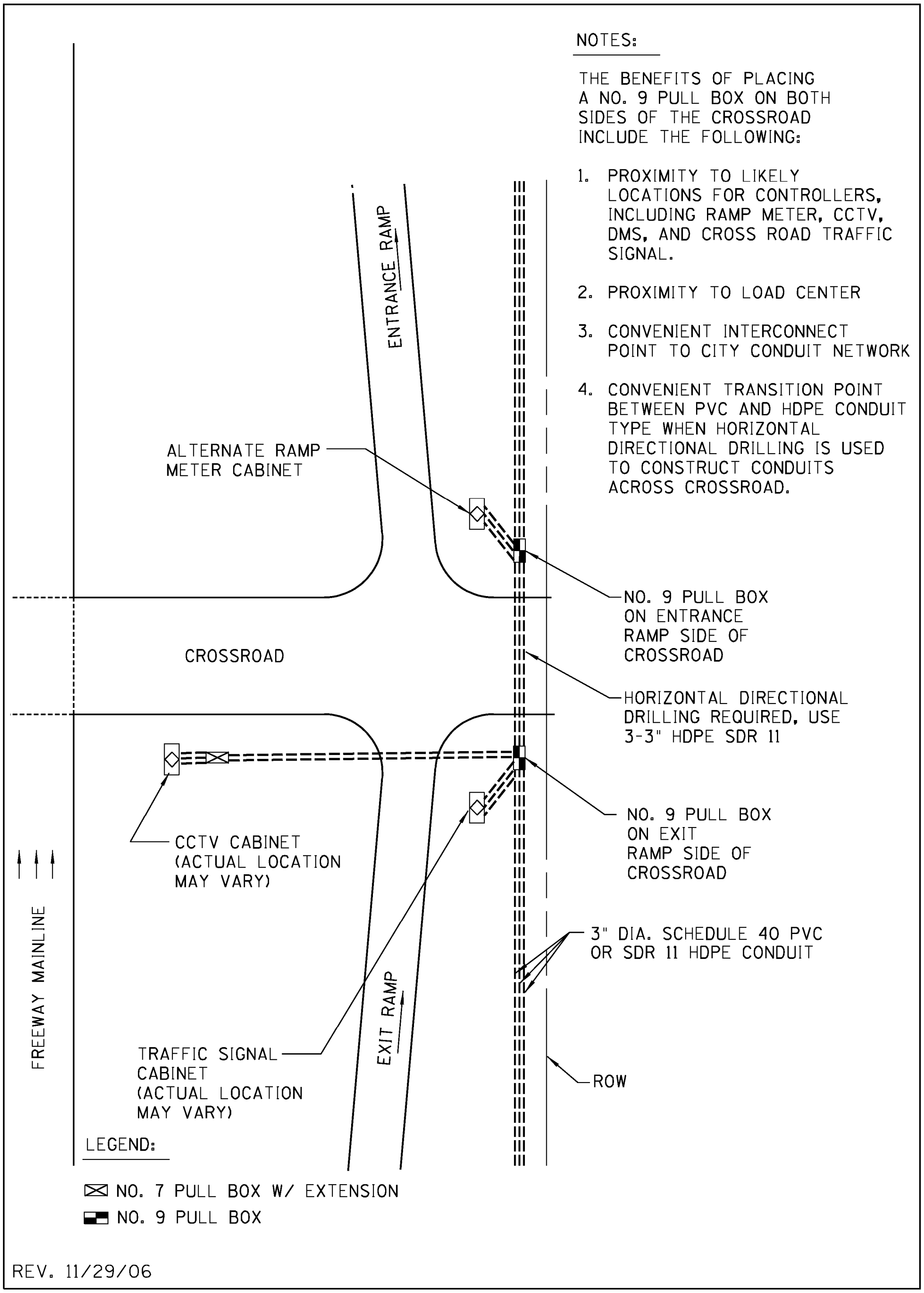


Figure 4.2 Trunkline Conduit Locations At Crossroad Interchanges

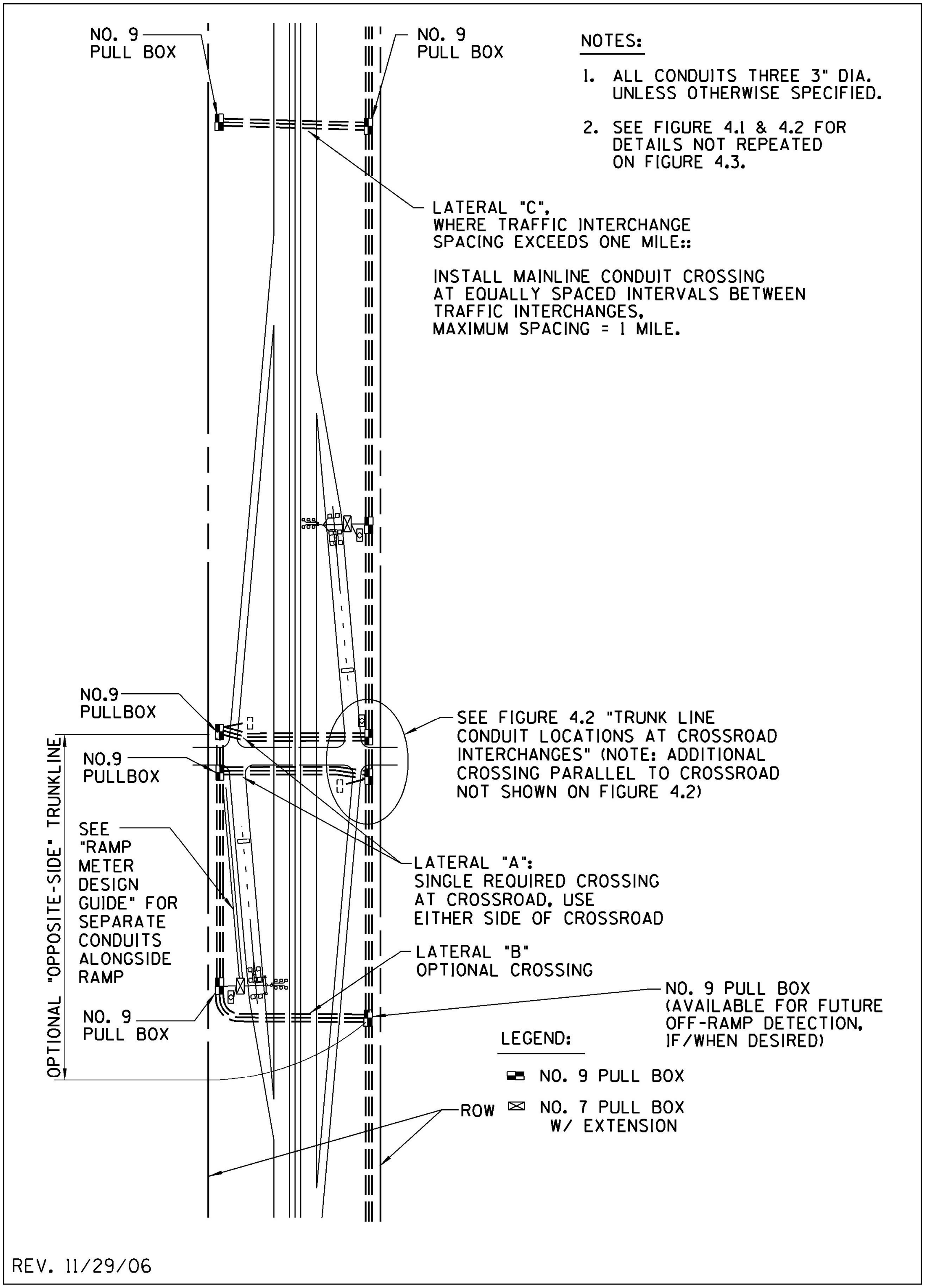


Figure 4.3 Conduit Installation on One Side of Freeway

4.4 Trunkline Conduit Co-Location with Lighting Power Conduits

It is incumbent upon the designer to analyze the cost effectiveness of joint trenching versus separate systems. As a general rule, if the length of the laterals necessary to connect the roadway lighting accessories to the trunkline exceed half the distance separating the roadway lighting appurtenances, then separate systems may be more cost effective since the total conduit and trench path would be greater for a joint system. Typically, the trunkline follows the right-of-way line to avoid impact by future widening. Separating lighting from fiber may alleviate theft or destruction of fiber in conjunction with copper lighting conductor theft. A cost analysis of both options should consider both one-time construction costs and ongoing maintenance costs. Any construction cost savings should be weighed against potentially higher maintenance costs.

When lighting conduit is co-located with the FMS trunkline conduit system, No. 7 lighting pull boxes should be located near each of the FMS trunkline pull boxes. In all cases, lighting circuit conductors and the FMS power conductors shall not share the same pull box. See Section 4.7.2.

4.5 Materials - Conduits

This section describes direct bury and horizontal directional drilling (HDD) conduits. Section 4.6 describes innerducts within conduits.

4.5.1 Conduit Connections at Communication Nodes and FMS Segment Termination Points

This section describes the conduit connections at communication nodes and termination points.

Communication Nodes

At each communication node building, redundant (geographically separated) conduits shall be provided to interconnect the trunkline conduits. Trunkline conduits extended along both sides of the freeway configured in a ring is the preferred approach to accomplish this geographic separation. Three-inch diameter conduits should provide interconnectivity between the node building and each of the two trunklines being used for redundancy. These conduits may be installed in one of several locations including under the mainline freeway via directional drilling, along the crossroad at a bridge underpass, or attached transversely to overpass bridge structures (see Section 4.5.4).

Trunkline Segment Termination Points

The designer should coordinate the lateral and vertical placement of trunkline conduits at project limits with adjacent design projects to ensure continuity of the conduit system and to ensure separation from other utilities.

4.5.2 Conduit Materials and Construction Methods

Conduits are constructed with either PVC or HDPE. All conduits shall have smooth inner and outer walls. (Innerducts are discussed in Section. 4.6.) PVC conduits are rated by wall thickness and crush resistance.

Schedule 40 is used for all applications where PVC is used. HDPE conduit is also rated for crush resistance and tear resistance. HDPE is subjected to significant pulling tension when used in HDD applications. Size Diameter Ratio (SDR) is a term that equates internal diameter and wall thickness to a universal rating. SDR 11 is judged from experience to be highly resistant to tear and crush forces for FMS HDD applications. To summarize, all conduits shall be smooth-walled and a minimum of Schedule 40 PVC or SDR 11 HDPE.

4.5.2.1 PVC and HDPE

All OSP conduits shall comply with NEMA TC-2 requirements.

- PVC pipe shall conform to ASTM D1784 and D1785 and UL 651 standard specifications. Fittings shall conform to NEMA TC-3 requirements.
- HDPE pipe shall conform to the standards published by the Plastics Pipe Institute (www.plasticpipe.org).
- Direct bury: In open trench installations, HDPE (SDR 11) pipe may be used instead of PVC Schedule 40. On long segments, continuous reels of HDPE may be easier to install than short PVC segments that require more labor to fit segments together. Gluing is not sufficient for joining segments of HDPE conduit as these runs shall be continuous and unspliced between pull boxes.
- Horizontal Directional Drilling (HDD): HDPE is required for all HDD locations. Splices are prohibited. All HDD conduits shall terminate in a No. 9 pull box.
- All transitions between PVC and HDPE conduits shall occur at No. 9 pull boxes (See Section 4.7, Pull Boxes).

4.5.2.2 Conduit Installation for Fiber-optic Cable: Maximum Pulling Tension, Bending Radius, and Deflection

The designer is responsible for designing a conduit system that will facilitate fiber-optic cable installation within and ensuring that the exerted force on the cable will not exceed 600 pounds of pulling tension during installation. Fiber-optic cable tends to have less tensile strength than other types of cable. Cable pulling programs that calculate pulling tension or previous design or construction experience are necessary to meet this requirement. Any bending should be a gradual deflection of straight conduit, and (as described in the next subsection) no single bend is to exceed one inch of deflection in one foot.

4.5.2.3 Fiber-optic Conduit Deflection

Conduit deflection should not deviate more than one inch horizontally and/or vertically per 12 inches of running length of conduit (1:12 rule). Long conduit sweeps should be used wherever possible to change conduit direction. The design should strive to stringently adhere to this requirement in order to reduce the pulling tension required during cable installation.

It is recognized that there are complex conduit sites that have to be addressed during design, such as crossings over canals, tunnels, transitions into structures, etc., where a 1:12 rule cannot be achieved. Where long conduit sweeps are not possible, standard factory-made conduit elbows of 11 ¼, 22 ½, or 45 degrees with a minimum radius of 24 inches should be specified. 90-degree cumulative turns must be made of individual elbows. Where complex sites leave no other option, such as into and out of structures requiring near 90-degree turns, a minimum radius of 36 inches is required. 90-degree elbows should be avoided, as they require additional labor and equipment for cable installation, even on short runs. The smallest degree of bend possible should be utilized to minimize cable installation challenges. There shall be no more than 360 degrees of cumulative bends between pull points (i.e., No. 9 pull boxes and cabinets).

4.5.2.4 Conduit Traceability and Detection – “Blue Stake”

The design of the fiber-optic conduit and cable must strive to avoid both potential damage to the conduit system and damage to the cable. Loss of communications is a critical issue with regard to the FMS.

Requirements for providing magnetic detection for the underground facilities of the FMS have changed throughout the years. The current ADOT policy, with regards to the FMS, is to place continuous detectable tracer wire within the conduit system for detectability. The tracer wire is required to be a minimum #12 AWG solid copper wire and shall be coated with a minimum 30 mil polyethylene jacket designed specifically for buried use. Typically, the tracer wire will be installed in the FMS power conductor conduit and the other conduits will have a pull tape installed. Detectable pull tape can be used as a substitute for pull tape, but not as a substitute for tracer wire since the detectable pull tape does not meet the minimum requirement of a #12 AWG detectable wire.

Branch conduits shall be constructed as *electrical* conduits for detection purposes, using No. 8 bare bond wire for traceability in accordance with the ADOT Standard Specifications (Section 732-3.01).

4.5.2.5 Conduit Protection

The following requirements are for any project that includes the installation of new FMS trunkline conduit or installation of fiber-optic/power/communications cables within an existing conduit system:

- The Contractor shall mandrel every conduit using a metal-disc mandrel with a diameter of 90% (80% for HDPE) of the inside diameter of the conduit.
- When considering the mandrel requirements for a specific project, the designer should be aware of the HDPE to PVC conduit transitions at No. 9 pull boxes. These transitions include a HDPE to PVC coupler that may have a smaller inside diameter than the PVC conduit and will be damaged or the conduit continuity will be compromised as the mandrel passes through.
- Immediately after the FMS conduits are installed, they shall be plugged to prevent the intrusion of water, mud, gravel, etc. The conduits shall also be re-plugged immediately after mandrelling, tracer wire and/or pulltape, and cable installation. An approved conduit plug is required to seal the conduits. Innerduct ends shall also be appropriately sealed.
- All conduits should always be fully protected from prolonged UV sunlight exposure, which can damage the conduit.

4.5.3 Conduit Trenching and Backfill

Several configurations of the trunkline are available to the contractor during construction (See Figure 4.4). The intent of allowing any of the approved configurations is to adapt to site specific conditions.

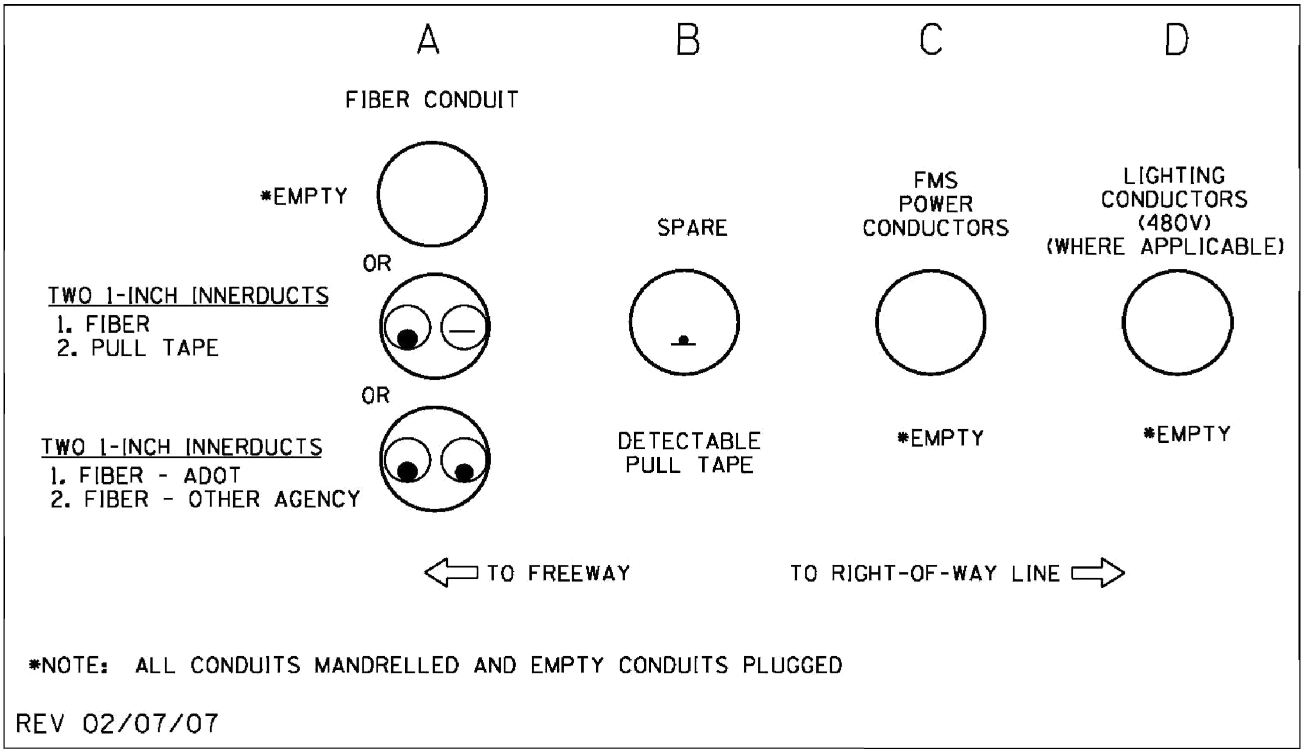


Figure 4.4 Trunkline Trench Configurations

The principal three-inch trunkline conduit contents are described herein and in Figure 4.4:

1. The conduit closest to the freeway (horizontal array) or on top (vertical array) is designated for single-mode fiber-optic (SMFO) cable, local agency fiber-optic cables, and other select device cables. All cables installed within the *fiber* conduit must be contained in innerduct (Section 4.6). Loose fiber-optic cables outside of innerducts are not preferred.
2. The second conduit (center) will be reserved for future FMS purposes and shall contain *pull tape.* This pull tape should be installed in the conduit as part of the initial conduit installation. The pull tape shall be minimum 2500 lb strength.
3. The third conduit is designated for FMS device electrical power distribution. Other select power cables, where required, such as power to ramp meter poles may also be allowed within an innerduct array. This conduit shall contain a minimum #12 AWG tracer wire when empty.
4. The fourth conduit is reserved for roadway lighting, when appropriate. (see Lighting Conduit – Section 4.4). This is not a preferred design standard and is shown only to demonstrate legacy design. This conduit shall contain a pull tape when empty.

Limited right-of-way width may also dictate a certain configuration such as a vertical stack. Where the conduit configuration is not horizontal, the fiber conduit is usually on top.

Conduit manufacturers offer *conduit spacers* (also called *duct spacers)* as an accessory product to support the installation of multiple conduits in one trench. Spacers provide stability, consistent separation, and relieve direct stress for conduit materials in direct bury and concrete encased applications. When installed with proper spacing to avoid excessive point deflections, spacers permit the contractor to backfill with native material instead of more costly encasement materials.

CLSM is a low strength version of *Utility Concrete for Miscellaneous Construction*, as described in the ADOT *Standard Specifications for Road and Bridge Construction*, Subsection 922. *CLSM* requires only 50 pounds (i.e., "½ sack") of cement per cubic yard, where *Utility Concrete* requires 470 pounds. *CLSM* is generally required in areas below existing improvements, since compacted native backfill could exhibit unacceptable settlement over time and lead to potential cracking or other structural failure of the improvement.

Generally, conduits may be arrayed vertically or horizontally. Two options for conduit alignment devices and their corresponding backfill guidelines are depicted in Table 4.1.

Table 4.1 Trench Conduit Alignment Device and Backfill Options

BACKFILL TYPE	CONDUIT ALIGNMENT DEVICE	FIGURE
Compacted backfill (native material, AB slurry, sand), or CLSM, except *CLSM* is required below existing improvements, such as pavement, driveways, and sidewalks.	Conduit Spacer	See Current ADOT FMS Standard Drawings from ADOT TTG PM
CLSM required	Conduit Spacer	See Current ADOT FMS Standard Drawings from ADOT TTG PM

4.5.3.1 Trench Encasement Material

Trench encasement material is the backfill material that encapsulates the conduits when CLSM is not required. The requirements for trench encasement material are described in the *ADOT Standard Specifications for Road and Bridge Construction*, subsection 203-5.03(B) (1 – Structure Backfill) and subsection 203-5.03(B) (2 – Use of Slurry). The designer should be aware that when subsection 2.03-5.03(B) (1 - Structure Backfill) is referenced for FMS applications, the gradation shall follow subsection 203-5.03(B) (2 – Use of Slurry) without the requirement of slurry material. Refer to the *FMS Standard Specifications* for additional information which may amend or supersede this specification.

4.5.3.2 Trench Backfill Material

Trench backfill material is the backfill material above the trench encasement material. Trench backfill material may be cementious or non-cementious in typical open trench situations.

- *CLSM* is not required, but it remains an option for the Contractor. It is certainly possible that trench and conduit installation operations may be cost effectively installed with *CLSM*. Cementious slurry is *required* where conduits in open trenches pass beneath existing pavement including driveways, sidewalks, and other locations.
- Either AB slurry, sand, or native backfill meeting standard specifications for compacted backfill may be used for conduit backfill (See *ADOT Standard Specifications for Road and Bridge Construction*, subsection 501-3.04(A) (2 – Trench Backfill)).

4.5.3.3 Trench Configurations with Conduit Spacers

Where conduit spacers are used, conduit spacers shall be capable of separating the conduits vertically and horizontally by the following minimum amounts:

- TRENCH LONGITUDINAL:

Maximum longitudinal spacer separation = 10 feet.

- VERTICAL:

Edge of trench to edge of spacer = two inches minimum;

Bottom of trench to bottom of lowest conduit = three inches;

Top of encasement material to top of highest conduit = six inches; and

Minimum set conduit separation shall be the diameter of the largest encasement material (sieve size: 100% passing), and not less than one and one-half inch.

- HORIZONTALLY:

Minimum horizontal conduit separation shall be twice the diameter of the largest encasement material (sieve size: 100% passing), and not less than one and one-half inch.

Spacers should result in the conduit system behaving as a cohesive unit to prevent *floating* of the conduits during backfill. Spacers above the top conduits should be used to ensure that floating is observed and corrected during backfill operation, and to verify there is a minimum 30-inch coverage above the top of the conduits (e.g., 24 in. above top of spacer).

4.5.4 Conduit Below Pavement and on Structure

This section describes conduits below pavement and on structures.

4.5.4.1 Conduit Installation on Structures: Bridges and Viaducts

The ADOT Bridge Group must approve any conduit installation within or attached to a bridge structure. Attaching conduit and associated hardware to the exposed fascia of new structures should be avoided; the conduit should be incorporated into the structure where possible. Conduits either within or attached to structures will be rigid metal conduit (RMC). RMCs are less likely to be affected by bridge expansion or deflection. Since this conduit is often hidden, it is imperative that the conduit system does not fail. Where required for aesthetic reasons, RMCs shall be painted to match the color of the existing bridge structure. Painting may require pre-treatment of the conduit.

Note: *This requirement may also be noted in the General Notes of the project plans.*

For bridge structures intended to convey the FMS trunkline, a RMC conduit system will be installed inside the box girder cells or under the bridge deck between the exterior and first interior girders. Designers must ensure adequate expansion couplings, allowing for conduit movement in all planes. Expansion couple devices should be provided at the same locations of bridge movement points. See Figure 4.5.

The placement of the FMS conduits in structures less than 1,760 feet in length should be in conformance with Figure 4.5. No. 9 pull boxes should be placed on either end of every structure where the FMS conduit trunkline is to be installed. Figure 4.6 depicts the conduit transition treatment between structures and No. 9 pull boxes. Conduit hanger placement details for I-beam and concrete box girder bridges are shown in Figure 4.7. The elevation of the conduit through the structure should approximate the elevation of the conduit placement in the trench in order to avoid sharp directional changes. The use of 90 degree conduit elbows to transition the conduit from the trench to bridge grade is not acceptable.

For bridges over 1,760 feet in length, in addition to the No. 9 pull boxes on each end, an intermediate pull box must be detailed into the structure to be accessible and to facilitate cable-pulling equipment. Intermediate pull boxes should be equally spaced along the structure at a maximum spacing of 1,760 feet. The designer will have to evaluate the accessibility of the area under or within the bridge to determine the appropriate location(s) for the intermediate pull box(s). Select bridges may require field devices, such as CCTV and controller cabinets, to be structure mounted. These devices, along with the pull boxes and associated conduit system, require special design of barriers, platforms, and pull boxes to accommodate the required field equipment. The FMS designer shall coordinate with the ADOT TTG PM on proposed field device locations on bridges as this type of installation is not the preferred location for the devices.

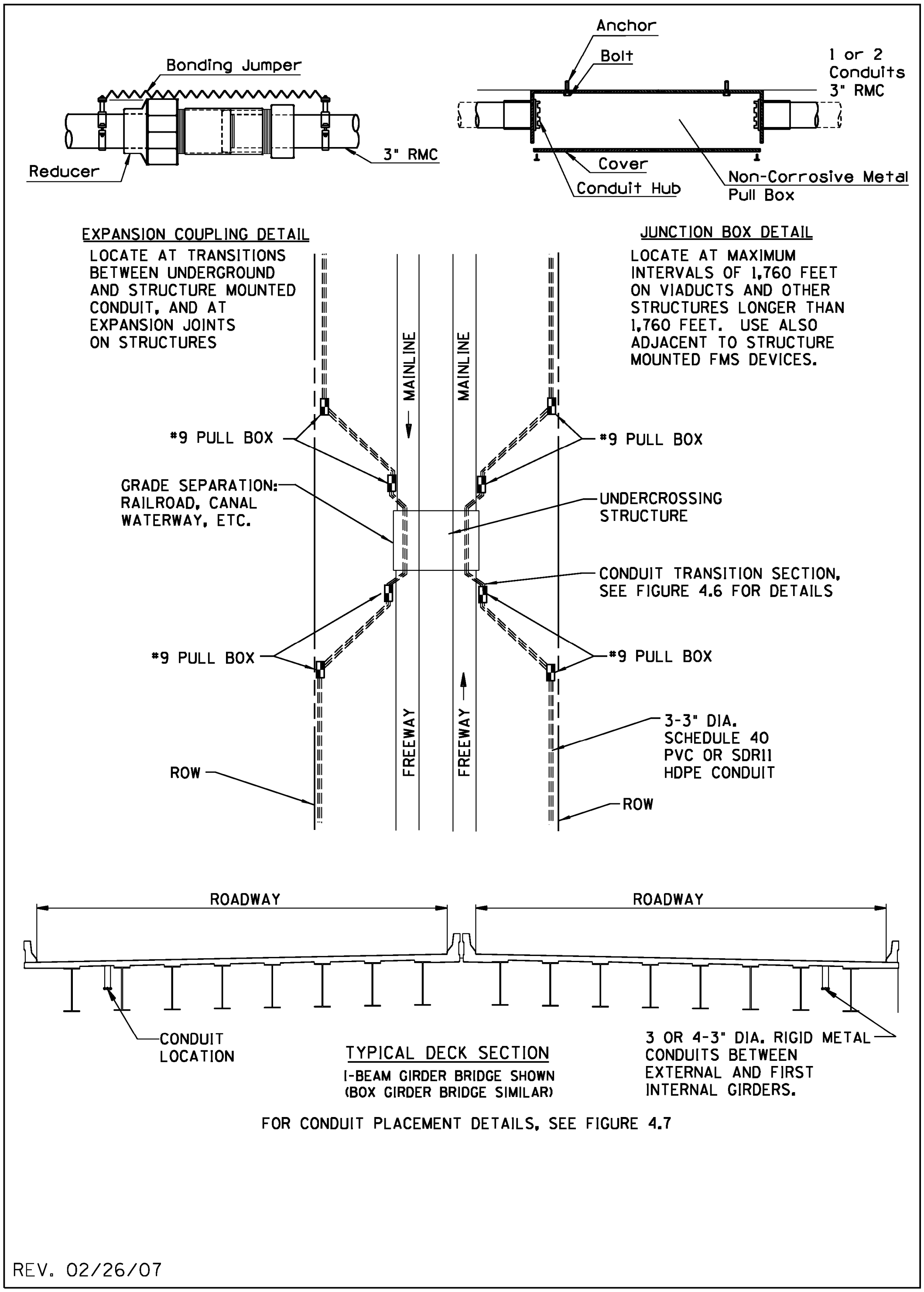


Figure 4.5 FMS Conduit Installation at Undercrossing Bridge Structure

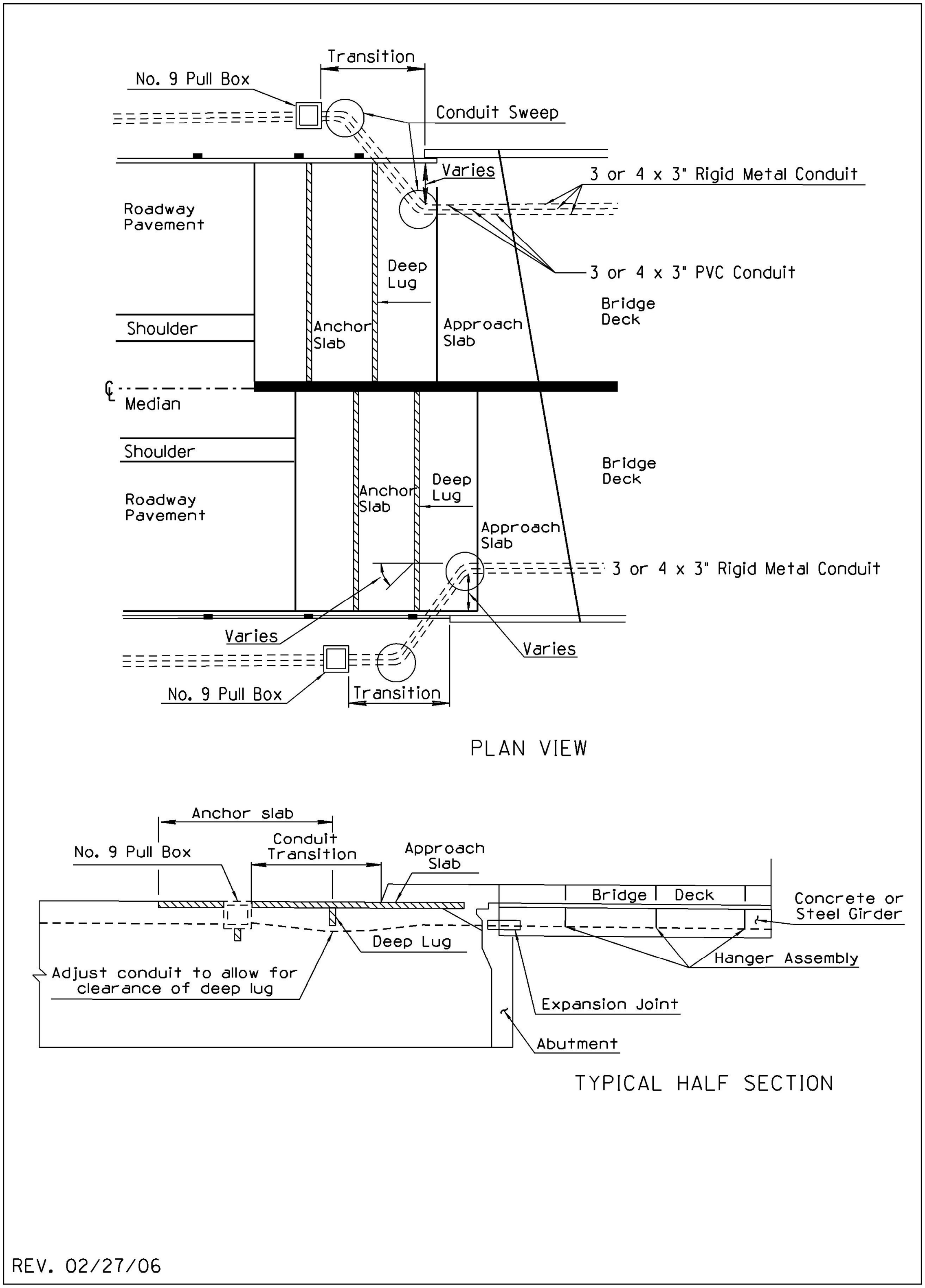


Figure 4.6 Conduit Transition at Bridges

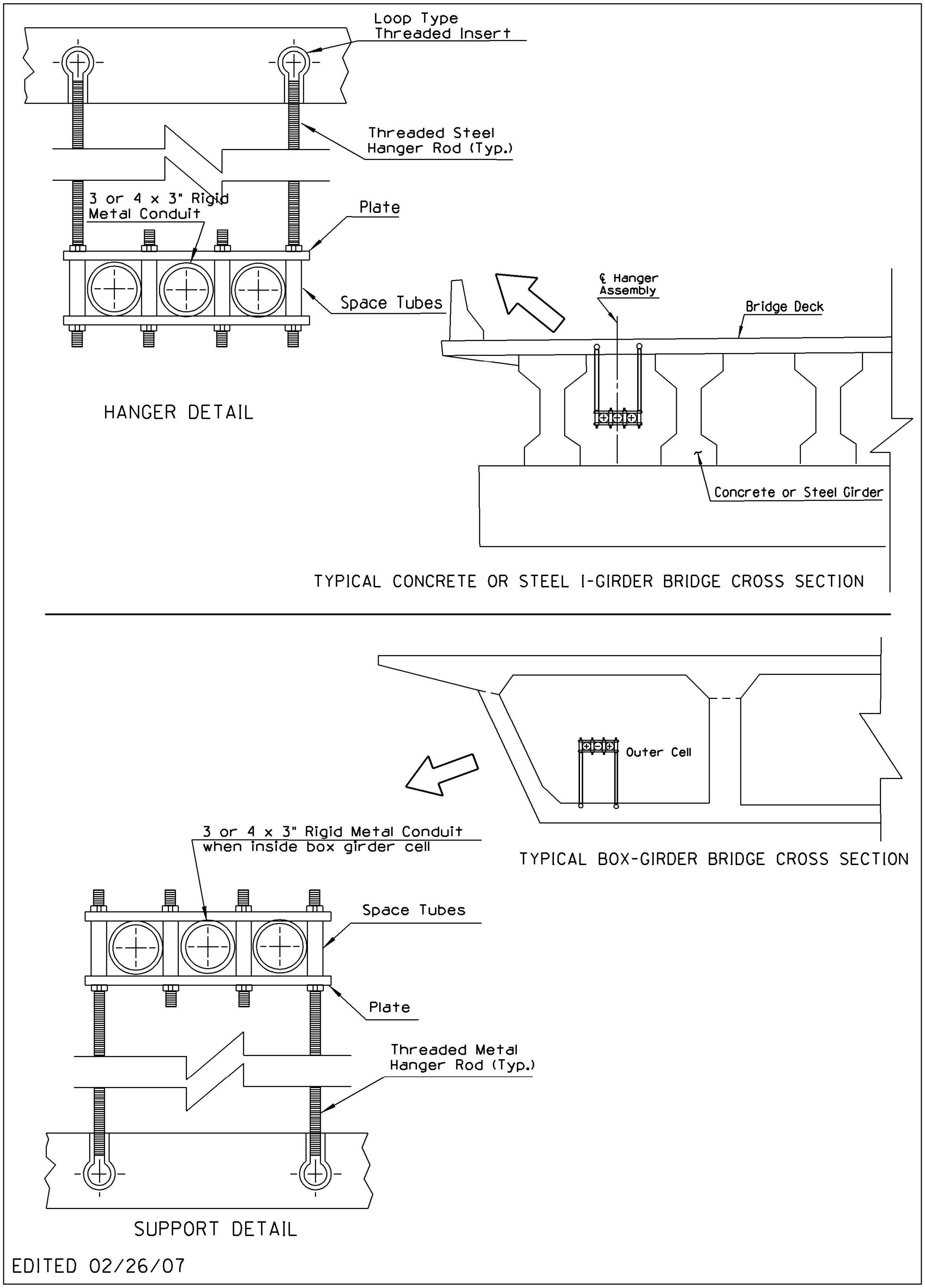


Figure 4.7 Conduit Attachment to Bridge

4.5.4.2 Conduits Crossing Ramps at Traffic Interchanges and System Interchanges

It is preferable to install trunkline conduit along the right-of-way line, hence at traffic interchanges, the trunkline conduits should be installed along the outside of the exit ramp, underneath the crossroad, and along the outside of the entrance ramp. In cases where this routing is not realistic, trunkline conduit may cross the exit ramp, run alongside the mainline or inside the entrance and exit ramps (crossing the crossroad either below pavement or on structure, see Figures 4.5, 4.6 and 4.7), and finally cross the entrance ramp back to the outside of the entrance ramp (see Figure 4.8 for ramp conduit crossings). This alternate configuration is shown on the right side of Figure 4.1.

Three ramp conduit-crossing cases are shown on Figure 4.8 and Table 4.2. The *preferred* conduit path should be gradual (1:12 rule) to avoid use of factory conduit bends. Both the *acceptable* and *least desirable* paths shown in Figure 4.9 involve use of factory conduit bends, the latter using two 90 degree turns to cross the ramp. The *least desirable* option should be discussed with, and ultimately approved by the ADOT TTG PM.

Table 4.2 Ramp Conduit Crossing Cases

RAMP CONDUIT CROSSING OPTIONS (SEE FIGURE 4.10)		
CASE A	Preferred	No factory conduit bends, maximum deflection of one-inch per foot of conduit.
CASE B	Acceptable	Maximum factory bend of 22½ degrees, 11¼ degrees bend preferred.
CASE C	Least Desirable	90 degrees factory bends, 36” radius. Requires prior approval from ADOT TTG PM.

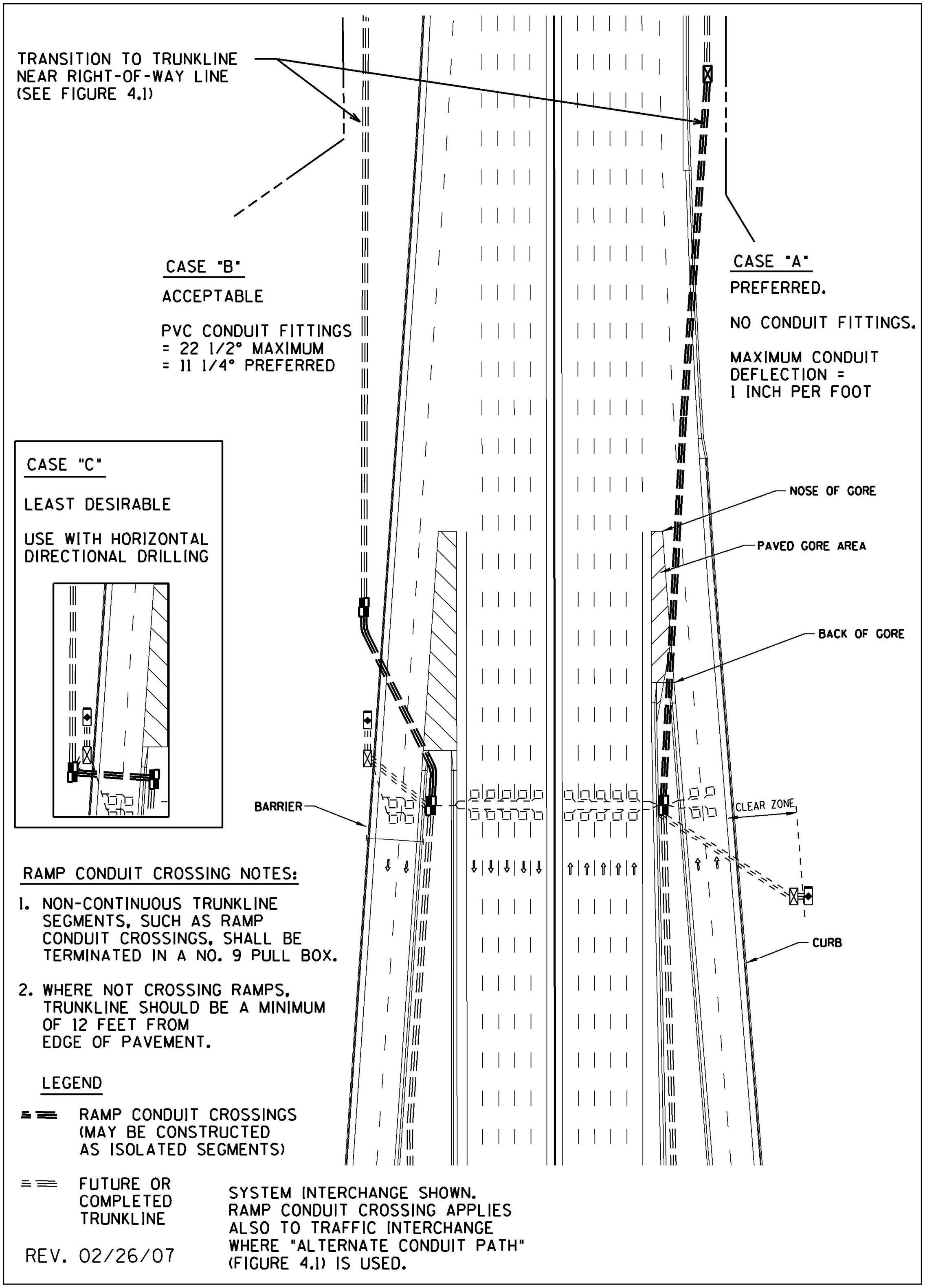


Figure 4.8 Ramp Conduit Crossings At Interchange Ramps

4.5.4.3 Conduit for Future Roadway Crossings

For projects where the continuous trunkline conduit is not being installed as part of the roadway construction project, designs must include provisions for installing roadway crossings where needed for future use. Usually this will occur at transverse crossroads. The designer should coordinate closely with the ADOT TTG PM for design of the trunkline 3-inch FMS conduits needed for the crossing. Available construction options include:

- HDD methods; and
- Open trenching where the construction of the crossroad is part of the civil improvement or where other unusual conditions exist, subject to ADOT TTG approval.

Irrespective of construction methodology, all conduits terminate in a No. 9 pull box. Transitions between two types of conduit (HDPE vs. PVC) must be made in a No. 9 pull box.

4.5.5 Horizontal Directional Drilling (HDD)

The Contractor may utilize HDD (also termed directional boring – DB) instead of conventional trenching at no additional compensation. The Contractor shall utilize HDD methods in locations under existing pavements, railroads, obstructions in areas where trenching would impact existing surface features, such as landscaping, that are not easily restored, and where indicated in the design plans. The designer should indicate HDD beginning and ending points on the plans. Warning tape is not required in conduit segments where HDD methods are used for construction.

The designer is referred to the following HDD reference documents:

- ASTM F 1962 – Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, including River Crossings;
- Mini Horizontal Directional Drilling Manual – published by the North American Society of Trenchless Technology (NASTT); and
- Polyethylene Pipe for Horizontal Directional Drilling-published by the Plastic Pipe Institute (PPI).

4.6 Materials – Innerducts

As noted in Figure 4.4, two innerducts are to be installed in the fiber-optic 3-inch trunkline conduit when ADOT and other agency fiber-optic cables may be installed on the same project, or where one fiber-optic cable is installed with the other fiber-optic cable to be installed subsequently. Otherwise, no innerduct is to be installed in the trunkline conduits when they are empty. Generally, two 1-inch innerducts of different color are to be installed in the 3-inch fiber-optic trunkline conduit when required. One innerduct shall contain the ADOT fiber-optic cable. The other innerduct shall contain the other agency fiber-optic cable, or pull tape (See Figure 4.4) to facilitate future fiber installation.

All innerducts shall be HDPE products with a nominal 1 inch diameter. No PVC innerduct is permitted. The two basic types of innerduct are *smooth walled* and *corrugated*. Corrugated innerduct was developed specifically to carry fiber-optic cables within larger conduits.

If a project requires three innerducts within a conduit, the designer shall verify the outside diameter of the innerduct such that all three innerducts will fit in the designated conduit. The specific outside diameter should be referenced in the project special provisions as well.

Corrugated innerduct:

- Is not rated by SDR, but is rated by inner and outer diameter, maximum pull load, and other characteristics;
- Has advantages over smooth walled innerduct, including:

a. Greater flexibility and elasticity;

b. Resistance to *ovalization*. Corrugated innerduct specifications generally call for a maximum ovalization of 5%, where smooth walled and ribbed innerducts allow 10%;

c. Resistance to *necking*. Smooth-walled innerduct tends to neck down at random points, where corrugated innerducts maintain their cross-section; and

d. No *reel memory*. Smooth walled innerduct is more rigid resulting in a greater possibility of retaining some of the curvature it had when on the reel.

- Increased inside diameter. When pulled to near its tensile strength, the inside diameter of corrugated innerduct tends to increase;
- Lighter weight. The reduced weight of corrugated innerduct often more than offsets its reduced tensile strength;
- Is available in tensile strengths comparable to smooth walled SDR-13.5 innerduct; and
- Is less suitable for runs over 1,000 feet.
- Smooth walled innerduct is:
- Available in varying wall thickness, described by the SDR. SDR 13.5 is appropriate for FMS innerduct applications. The safe pulling tension for SDR 13.5 typically exceeds 400 lbs;
- Is more suitable for runs longer than 1,000 feet;
- *Ribbed* innerduct has longitudinal ribs on the inside, outside, or both surfaces. Outer ribs interlock with the ribs of the second innerduct, reducing *spiraling* of the two innerducts. Outer ribs also reduce the friction between the conduit and the innerduct during innerduct installation. Inner ribs reduce the friction between the innerduct and the fiber-optic cables during fiber installation. Both inner and outer ribs facilitate the spread of lubricants; and
- The designer should consider various factors when choosing innerduct. Generally, *ribbed* innerduct is preferred for runs over 1,000 feet, and corrugated innerduct is preferred for shorter runs. However, where the tensile strength of corrugated innerduct is rated equal to or higher than that of SDR 13.5 smooth walled or ribbed innerduct, and there is no other apparent disadvantage to the corrugated product, corrugated innerduct may be considered for longer runs.

Innerduct Construction and Inspection

The specification for innerduct installation should include a requirement for the Contractor to blow a plug (pig) through the innerduct to demonstrate that the innerduct was installed properly (e.g., not twisted, crimped, necked or ripped) in accordance with industry practice.

4.7 Pull Boxes

FMS pull boxes are used in ground and structure mounted applications. Two sizes or types of FMS ground-based pull boxes are normally used on FMS projects: The “box” sized *No. 7 with extension* and the “vault” sized *No. 9* (see Section 4.7.1 for further description of pull box types). Pull Boxes on slopes should normally be constructed with the lid level, not tilted to be parallel with the slope. Pull Boxes should also be designed to avoid exposing the side of the pull box that might be a hazard to traffic.

Pull boxes should not be installed within the roadway, within any paved area, or future roadway footprint unless each location is explicitly approved by ADOT TTG and compliant with additional load and lid requirements where applicable.

Pull boxes should not be positioned in locations that are known paths for vehicles, such as maintenance and landscaping trucks, nor in roadway shoulder or distressed vehicle pullouts. Designers should field check each new proposed pull box location to ensure that it is not in a location where it would likely be in the path of vehicle traffic.

Care should be taken in locating pull boxes to avoid drainage swales. Generally, pull boxes should be elevated above the surrounding terrain between one and two inches. Thus the requirement to have the designer pre-position the pull box within the design is no longer required. The designer is expected to field verify the proposed pull box locations to avoid any known conflicts.

The field inspection team, along with the Contractor, must position pull boxes to avoid drainage swales or wheel-loads. Where necessary to avoid these locations, the pull box spacing may be reduced and the number of pull boxes required increased. Pull box locations can be more easily checked to avoid adverse locations if the contractor marks the proposed trunkline path in the field prior to construction.

Pull Boxes should comply with NEC internal dimension requirements described in Article 314, with consideration of cable size and bending radius.

Delineators are not required to mark pull box locations.

All pull box lids shall be labeled “ADOT FMS,” consistent with current practice.

4.7.1 Pull Box Types

Two types of FMS in-ground pull boxes, No. 9 and No. 7 with extension are illustrated in Figure 4.9, 4.10, and 4.11. See the *FMS Standard Details* for additional detailing of pull boxes. Pole mounted and bridge mounted pull boxes are also described in this section.

No. 7 Pull Boxes with Extension- General

All No. 7 pull boxes on FMS projects shall include an extension. As illustrated in Figure 4.9, there are two types of No. 7 pull boxes with extension; one for use with branch fiber-optic cables (on branch conduits only, all trunkline fiber shall pass only through No. 9 pull boxes), and one for use with electrical conductors (for use on both trunkline and branch conduits). No. 7 pull boxes with extension are installed along the trunkline conduit system to facilitate cable pulling, to provide access to the trunkline conduit system for power conductors, or for other laterals not requiring splicing or coiling of the fiber-optic cable. Electrical No. 7 pull boxes with extension are to be located a maximum of 900 feet apart along the trunkline conduit system. Typically, only the third conduit containing electrical conductors is swept up into the No. 7 pull boxes with extension, while the remaining conduits bypass the box. Conduit entering No. 7 pull boxes with extension shall have molded bell ends to protect the conductors/conduit during installation. Only one 12-inch extension is allowed for FMS applications. All conduit sweeps into the No. 7 pull box with extension shall be PVC, not RMC or HDPE.

No. 7 pull boxes with extension shall be numbered and geo-referenced. No. 7 pull boxes with extension on each FMS project shall be designated with a unique number that is not duplicated. <u>Re-use of pull box numbers on each plan sheet shall no longer be an acceptable design format.</u> The pull box numbering scheme should be similar to the ADOT cabinet numbering scheme, e.g., by route, direction, and milepost to the nearest hundredth of a mile.

Designer's special provisions must include the "as-built documentation" bid item. The Contractor must provide GPS coordinates under the bid item for each new and existing No. 7 pull box with extension within the project limits. ADOT TTG will not provide GPS devices to the contractor. GPS devices should not be a bid item unless otherwise directed by ADOT TTG. The designer will need to coordinate with ADOT TTG on the GPS data collection and format requirements. The designer's plans need to provide placeholders for the Contractor to fill in coordinates to record as-built information.

4.7.1.1 No. 7 Pull Boxes with Extension- Loading Requirements

All FMS No. 7 pull boxes and extensions shall be designed, tested, and certified to meet AASHTO *"HS20-44"* and ASTM C 857 *"A-16"* loading requirements, including impact factor. The maximum AASHTO loading applies regardless of whether the older Load Factor Design (*LFD*) or newer Load and Resistance Factor Design (*LRFD*) methods are used, and is applicable to all pull box elements except for steel lids. Steel pull box lids are not to be used for No. 7 with extension pull boxes. There are industry standard composite pull boxes with extension that meet the specified load requirements. The *No. 7 Concrete Pull Box* shown on ADOT *Std Dwg T.S. 1-3* and the *No. 7 Concrete Pull Box Extension* shown on ADOT *Std Dwg T.S. 1-4* do not meet these loading requirements.

<u>Sample design load calculations (except for steel lids), applied to any 8" x 20" area on the pull box lid:</u>

LFD: 16,000 lbs x 1.3 x 1.67 x 1.3 = 45,157 lbs

LRFD: 16,000 lbs x 1.75x 1.2 x 1.33 = 44,688 lbs

<u>Sample design load calculations for steel lids, applied to any 8" x 20" area on the pull box lid:</u>

Allowable Stress Design: 16,000 lbs x 1.3 = 20,800 lbs.

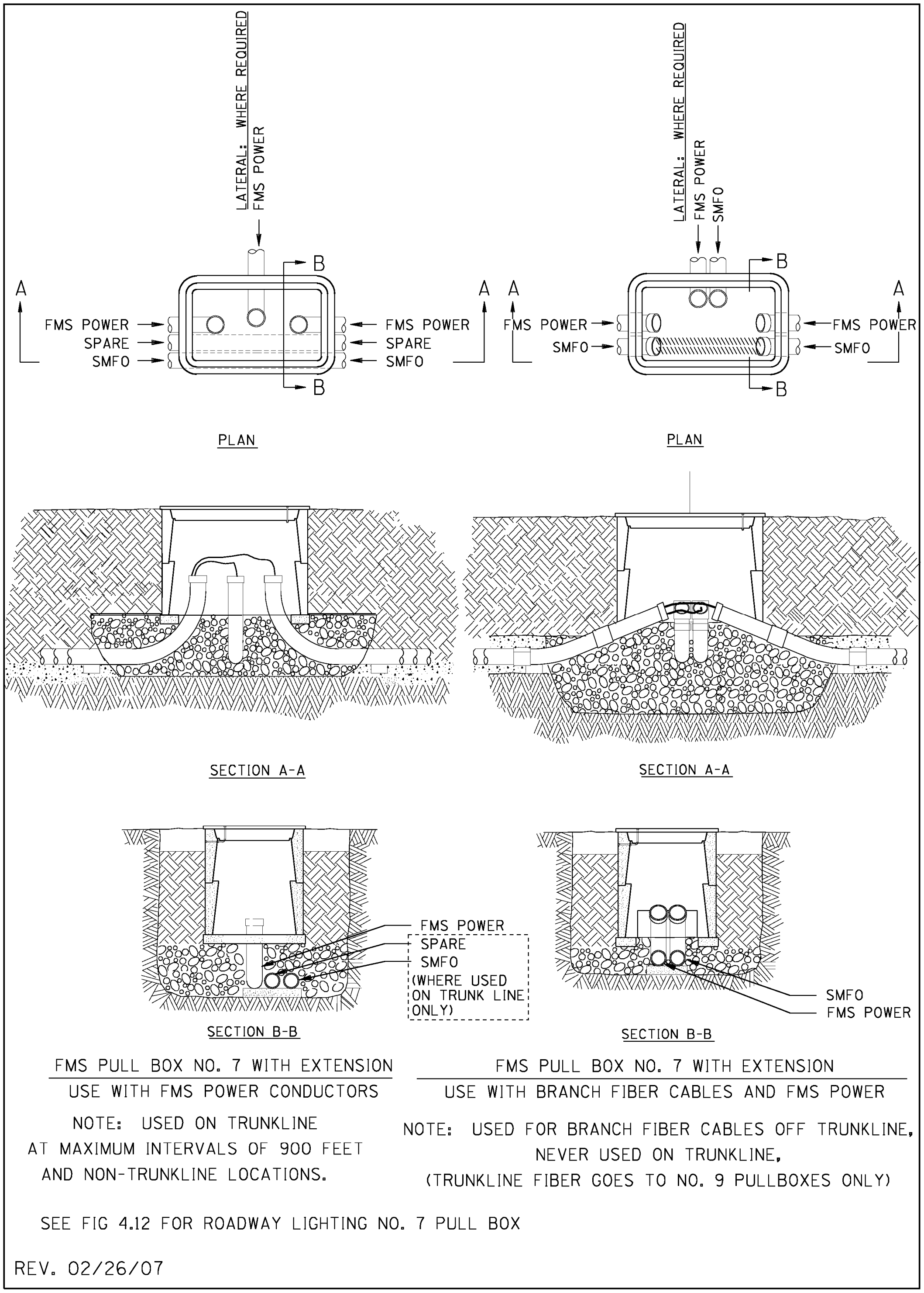


Figure 4.9 FMS No. 7 Pull Box with Extension

4.7.1.2 No. 9 Pull Boxes - General

No. 9 pull boxes with *"Term-a-ducts"* (or equivalent) ports for conduit entry are to be installed in the following instances:

- Approximately every 1,500 feet along the trunkline to assist installation of fiber cabling within the conduit (in the rare case where there is a continuous mile without interchanges, No. 9 pull boxes may be spaced 1,760 feet [1/3 mile] to conform to the one mile spacing of traffic monitoring stations);
- In the vicinity of each mainline detector station, approximately one mile spacing;
- Each location where fiber-optic cable splicing occurs or may occur; and/or
- Potential splice points for branch fiber-optic cable to Freeway DMS controllers, CCTV cameras, traffic signal controllers, or other field devices.

The No. 9 pull box depth should not be greater than 48 inches. The extension shown for No. 9 pull boxes on ADOT Standard Drawing T.S. 1-7 is discontinued for FMS use. <u>No extensions may be added to a No. 9 pull box under any circumstances when intercepting an existing empty conduit system.</u> The designer should coordinate with the ADOT TTG and ITS maintenance staff when existing cables are present in the existing conduit system to be intercepted.

Placement of No. 9 pull boxes should also consider the conduit routing be placed on each terminus of HDD conduits, at each end of structures, at node building sites, and at logical regional communication tie points.

See Figures 2.1, 4.1, 4.2, 4.3, and 4.8 for placement of field element devices relative to the trunkline conduit system.

4.7.1.3 No. 9 Pull Boxes – Loading Requirements

FMS No. 9 pull boxes not located in paved or other areas where repeated wheel loads are expected shall be designed, tested, and certified to meet AASHTO *"HS20-44"* and ASTM C 857 *"A-16"* loading requirements, excluding impact factor. This design load would be appropriate for slow moving wheel loads by ADOT maintenance and landscaping vehicles. The AASHTO loading applies regardless of whether the older Load Factor Design (*LFD*) or newer Load and Resistance Factor Design (*LRFD*) methods are used. Note that steel lids for No. 9 pull boxes should be designed to the same design loads required for the remainder of the pull box (unlike No. 7 with extension pull boxes, where the *allowable stress method* for steel may be used). This standard is easily met since all No. 9 pull boxes require steel lids (see Section 4.7.1.5).

<u>*Sample design load calculations, applied to any 8" x 10" area on the pull box lid:*</u>

LFD: 8,000 lbs x 1.3 x 1.67 = 17,368 lbs

LRFD: 8,000 lbs x 1.75 x 1.2 = 16,800 lbs

Where No. 9 pull boxes must be located within the traveled way, shoulder, other paved surface, or other location where repeated dynamic loads are likely (such as unpaved areas near ramp gores), a special design of the pull box lid must be conducted by the designer to accommodate the repetitive vehicular loading. The pull box lid design must incorporate a locking mechanism that will prevent vibration and vehicle traffic from un-seating the lid. This design should be coordinated with the ADOT TTG PM.

4.7.1.4 No. 9 Pull Box – Cable Racking

Fiber-optic cable is coiled in No. 9 pull boxes. The cables are supported on the sides of the pull box with pre-manufactured vertical cable racks called *cable ladders*. Trunkline conduits typically enter the No. 9 pull box from opposite corners. See Figure 4.10.

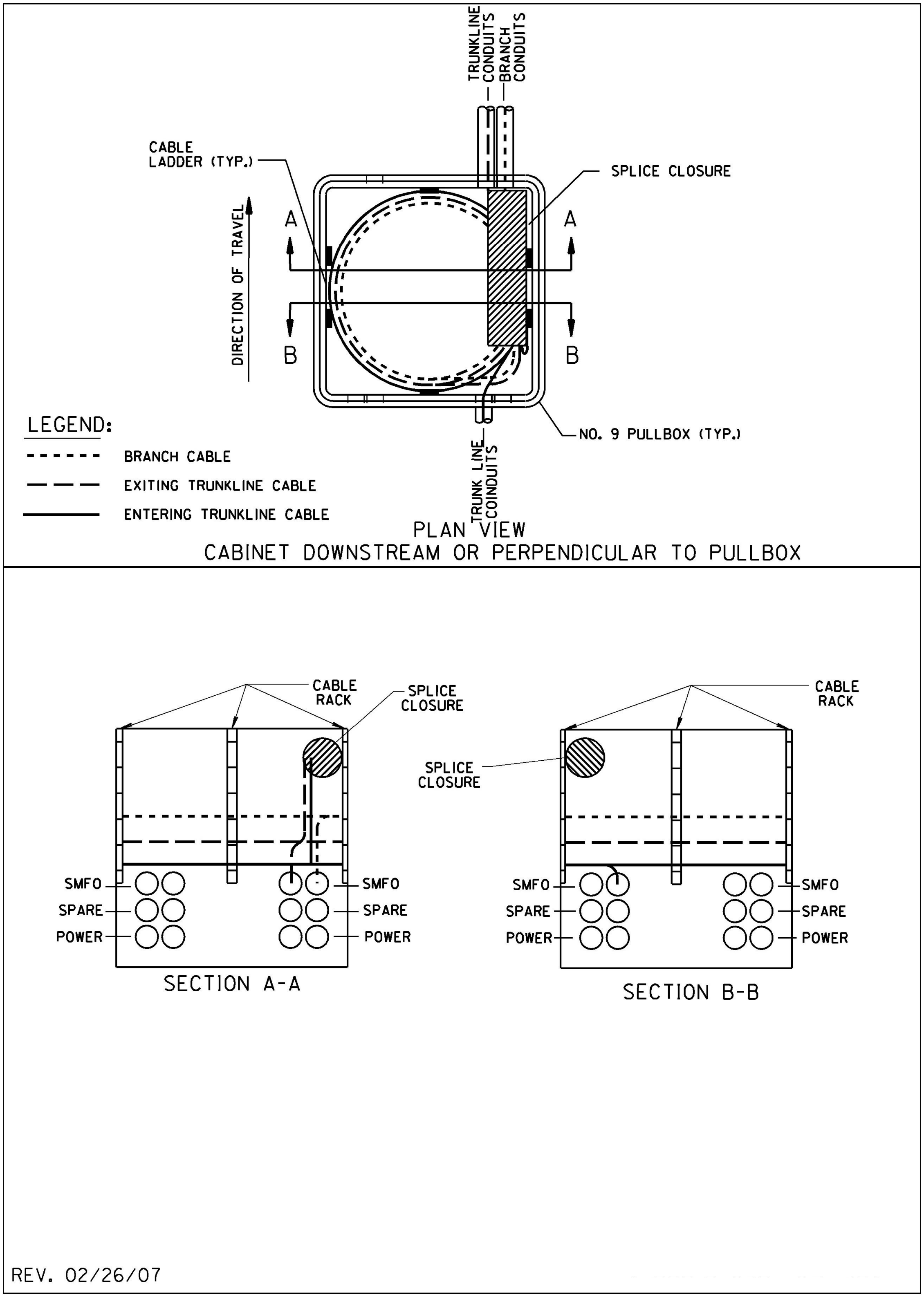


Figure 4.10 No. 9 Pull Box Conduit Routing

4.7.1.5 No. 9 Pull Box – Torsion Assist Lid

The diamond-plate steel lid for No. 9 pull boxes shown on ADOT Standard Drawing TS 1-7 is discontinued for FMS use. No. 9 pull boxes shall incorporate a new lid design with the following requirements (see Figure 4.11):

- Single hinged lid, galvanized steel;
- Generally open to 180 degrees, (intermediate opening shall not be allowed);
- Failsafe lid lock in open position;
- Torsion assist by galvanized steel spring mechanism, not hydraulic or fluid system;
- Torsion assist in both directions; and
- Locking hardware, galvanized steel.

Lift effort opening and closing shall not exceed 30 pounds of force. It will be the designer's responsibility to coordinate with the ADOT PCD ITS Maintenance group to verify No.9 pull box torsion assist lid requirements.

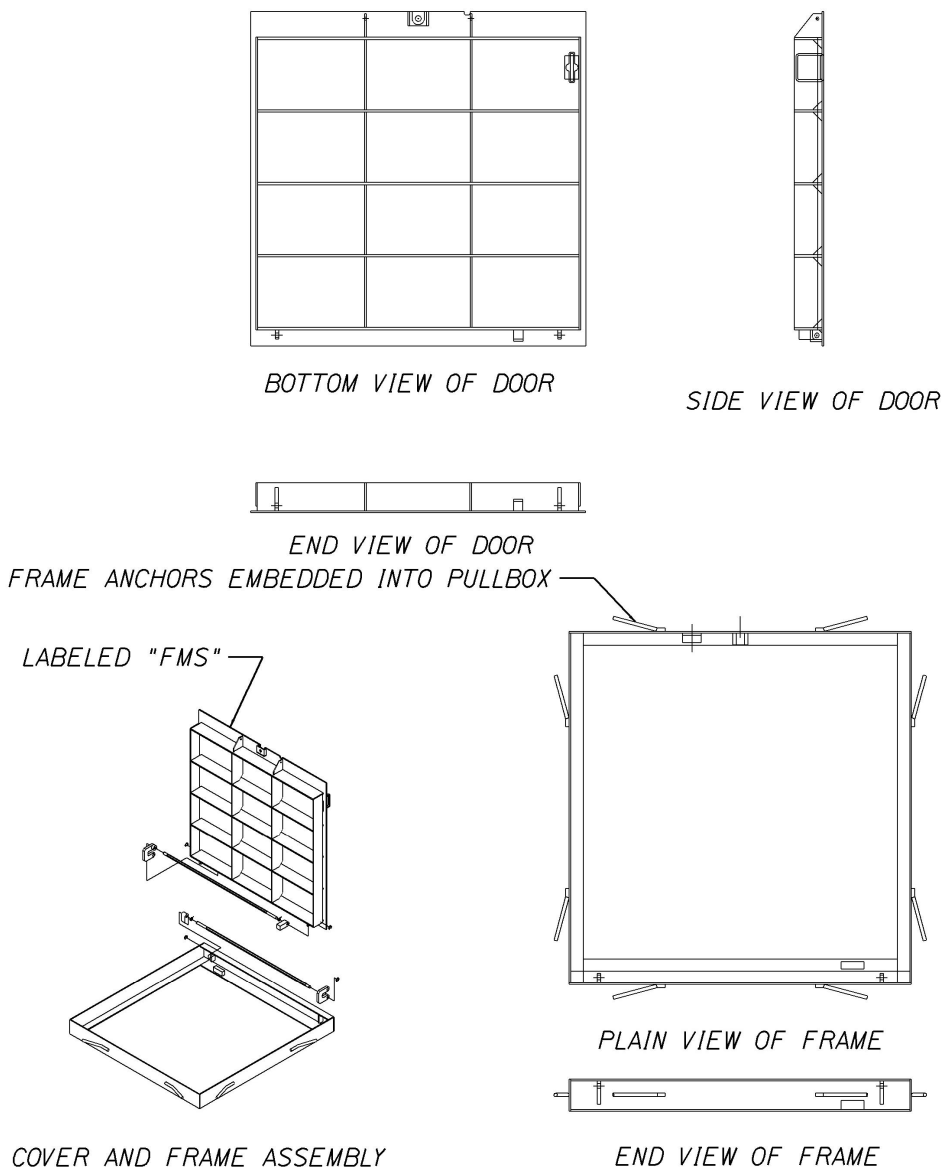
4.7.1.6 No. 9 Pull Box – Splice Closures

Stand-alone splice closures for fiber-optic cables include housing, splice trays, fiber-optic splices, and splice protective sleeves. Splice closures should meet Telcordia GR-771-CORE Standards and be compatible with the type of fiber-optic cable used. Splice protective sleeves should be the heat shrink type.

4.7.1.7 No. 9 Pull Box – Numbering and Geo-referencing

No. 9 pull boxes shall be numbered and geo-referenced. No. 9 pull boxes on each FMS project shall be designated with a unique number that is not duplicated. Re-use of pull box numbers on each plan sheet shall no longer be an acceptable design format. The pull box numbering scheme should be similar to the ADOT cabinet numbering scheme, e.g., by route, direction, and milepost to the nearest hundredth of a mile.

Designer's special provisions must include the "as-built documentation" bid item. The Contractor must provide GPS coordinates under the bid item for each new and existing No. 9 pull box within the project limits. ADOT TTG will not provide GPS devices to the contractor. GPS devices should not be a bid item unless otherwise directed by ADOT TTG. The designer will need to coordinate with ADOT TTG on GPS data collection and format requirements. The designer's plans need to provide placeholders for the Contractor to fill in coordinates to record as-built information.



NOTES:

1. LID OPENS TO 180 DEGREE POSITION.
2. EXCLUDE ALL PROVISIONS FOR 90-DEGREE OPEN POSITION
3. EASILY OPENED AND CLOSED BY ONE PERSON, MAXIMUM FORCE REQUIRED TO OPEN/CLOSE = 30 LBS
4. TORSION ASSIST WITH SPRING MECHANISM. NO HYDRAULIC SYSTEM WITHOUT ADOT TTG APPROVAL.
5. LOCKING HARDWARE REQUIRED.
6. NON-DYNAMIC TRAFFIC LID.

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Figure 4.11 No. 9 Pull Box Torsion Assist Lid

4.7.1.8 Pole Mounted Junction Boxes

All poles intended to support non-intrusive vehicle detection systems shall be accompanied with an adjacent pull box. The pull box may be placed in the ground (No. 7 with extension) or, in cases of barrier pole mount sites, a special NEMA junction box mounted on the pole near the base of the pole shall be designed. Pull boxes in barriers are not required unless directed by the ADOT TTG PM.

4.7.1.9 Bridge Mounted Junction Boxes

Conduit crossings over canals, roadway undercrossings, railroads, etc. that are to be mounted on the exterior of the bridge fascia shall have secure junction box covers added. The junction box covers shall be designed so that special tools are required for the cover plate to be removed to thwart vandalism.

4.7.2 Co-Locating Lighting No. 7 Pull Boxes with FMS Trunkline Pull Boxes

As noted in Section 4.4, lighting power conduit may be co-located with the FMS trunkline where it is advantageous, though this is not the preference of the lighting maintenance group or ADOT FMS maintenance. No. 7 lighting pull boxes should be co-located with FMS No. 9 and No. 7 with extension pull boxes. This ensures that the lighting conduit can be accessed without disturbing the trunkline and FMS power cables where they are co-located. See Figure 4.12.

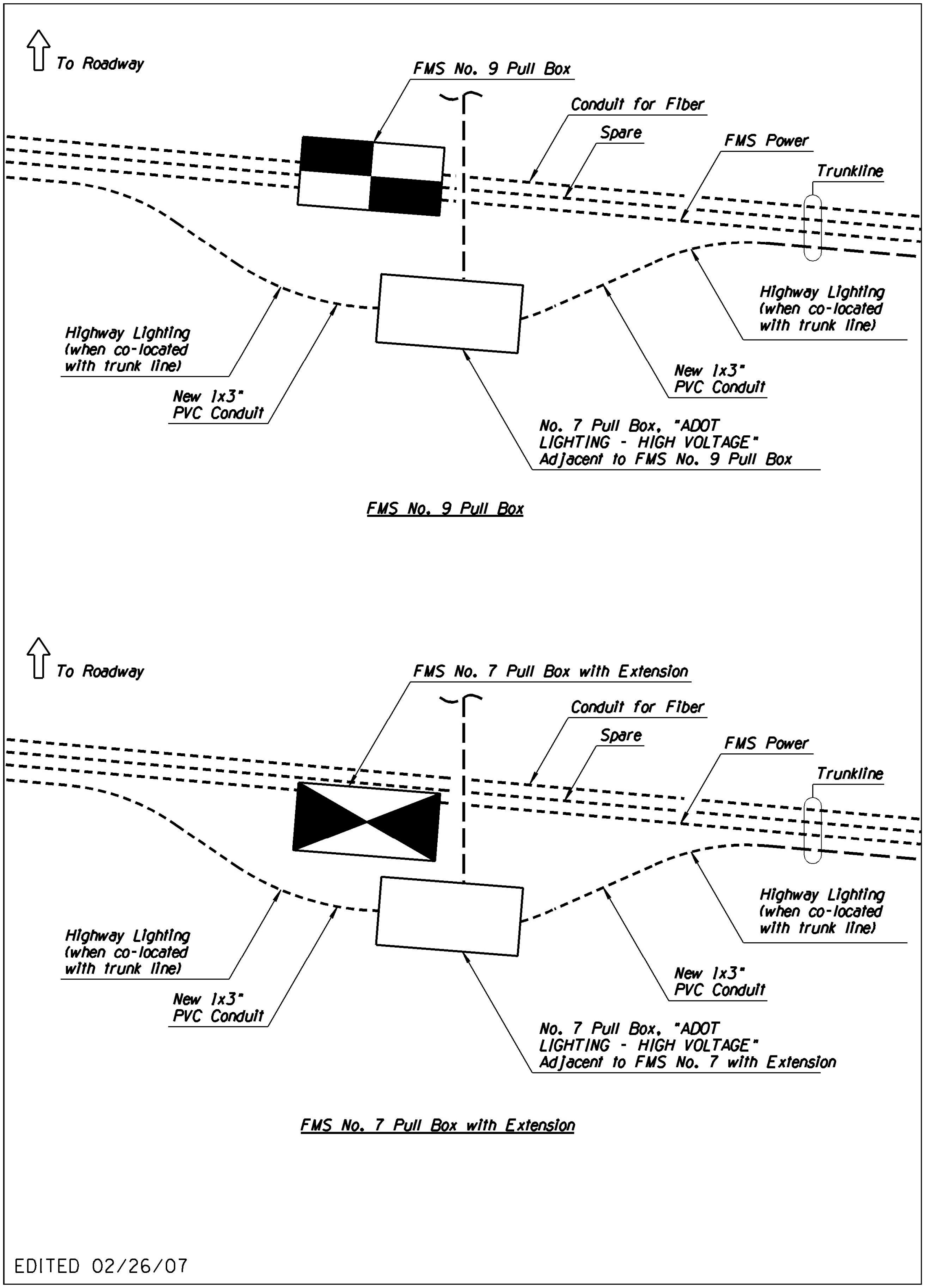

Figure 4.12 Roadway Lighting No. 7 Pull Box

4.7.3 Cable Labeling at Pull Boxes

Durable labels approved by the engineer should be installed on each conductor/bundle of conductors and cable near the point where it enters/exits the pull box. A cable passing through a pull box, whether spliced or not, will have two labels, one near each exit/entry point within the pull box. The cable label shall be designed to slide along the cable to facilitate examination.

The two labels for the cable will be similar, but will always differ in the “destination”. A typical trunkline No. 9 pull box with one branch fiber-optic cable would have three labels, two on the trunkline fiber-optic cable (one on each side of the splice closure) and one on the branch fiber-optic cable. All labels should include, where applicable:

- The word “CAUTION”;
- Cable type and number of strands/conductors, such as:
- “SMFO96” (single mode fiber-optic, (SMFO 96 strands);
- “AWG6” (American Wire Gauge, No. 6);
- “IMSA 5” (IMSA 19-1 5 conductor cable, IMSA 50-2, etc.);
- “DLC” (Detector Loop Cable); and
- Loop Detector Lead-In Cable;
- Composite (typically vendor supplied, specific for CCTV, Freeway DMS or non-intrusive detection technology applications);
- Voltage;
- “480 Volts”;
- “120 Volts”;
- (low voltage cables do not need to be labeled for voltage); and
- Destination – The following table suggests a destination labeling strategy intended to be consistent, simple to create, and simple to use.

Table 4.3 Destination Labeling Strategy

CABLE LABELING: DESTINATIONS "TO_________":			
TYPE	USE	DESTINATION	EXAMPLES
Fiber-optic	Trunkline	Next: Terminal point for FMS segment Node Building	"TO Val Vista" "TO Node 12" "TO TOC"
Fiber-optic	Branch	Trunkline and side of freeway	"TO EB Trunkline"
		Cabinet Number	"TO CAB 3118253"
Power	Load Center to Cabinet	Load Center Number	"TO LC 3118256"
		Transformer Number	"TO XFRM 3118279"
		Cabinet Number	"TO CAB 3118253"
Loop Lead-In Cables	Detector Loops to Pull Box	Lane Number, "U" – Upstream or "D" – Downstream	"TO 5U" (to lane 5 upstream loop)
Detector Loop Cables	Loop Station to Cabinet	Loop Station: Mainline: Direction of travel Ramp: Start and end ramp direction	"TO EB Loop Station" "TO E-N Loop Station"
		Cabinet Number	"TO CAB 3118253"

Cable labels may be bundled around multiple conductors; for example, power conductors coming from one load center and going to four cabinets:

- The conductors coming from the load center entrance to the pull box may be bundled with a label "TO LOAD CENTER ____"
- The conductors heading to the four individual cabinets would have one label per cabinet, thus four bundles, each labeled with the appropriate cabinet number "TO CAB _______"

4.7.4 Fiber-Optic Cable Installation Sequential Reports

After each cable installation, the Contractor shall record the fiber cable foot marking at the entrance and exit point in each No. 9 pull box for each fiber cable on a Fiber-Optic Cable Installation Sequential Report. This report should be submitted to ADOT prior to final acceptance.